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CLOVER STEM ROT

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CLOVER STEM ROT[1]

By
FREDERICK A. WOLF AND R. O. CROMWELL

INTRODUCTION[2]

There has been present for several years in North Carolina a stem rot disease of crimson clover, Trifolium incarnatum. This disease has attracted attention because it results in the death of all plants in well-defined areas, involving in some instances, spots of considerable extent. Numerous inquiries as to the cause of this condition have been received during the past few years at the North Carolina Experiment Station and have led to an investigation of the nature of this stem rot disease. Furthermore, the growing importance of crimson clover as a cover crop and as an invaluable means of increasing and maintaining soil fertility makes it desirable to circulate the facts established by this investigation as widely as possible. It seems advisable, therefore, to present at this time, data bearing upon the history and distribution of the disease, on the relationship and life history of the causal organism, and on methods for the prevention and control of its ravages.

Historical

The disease in epidemic form has long been known in Europe and was observed as early as 1857 (14, 15, and 18) near Beberbeck, in the province of Hesse, Germany. Here it appeared in a field seeded with a mixture of red clover, Trifolium pratense and white clover, Trifolium repens, and was noted to be more destructive during the moist winter weather than during the preceding dry autumn. In 1870 it was first noted in Denmark and by 1878 it had spread to Sweden.

Two extensive accounts of this disease in Europe have appeared, one by Rehm (18) in 1872 and the other by Eriksson (6) in 1880. The first of these deals primarily with the morphology and development of the causal organism which is identified as Peziza ciborioides Fr. It also contains suggestions for the control of the disease and a record of observations upon the host species which were found to include red clover, white clover, crimson clover, and alsike clover, Trifolium hybridum. Among the other leguminous plants which were exposed to infection, but which remained healthy were alfalfa, Medicago sativa, sainfoin, Medicago falcata, black medic, Medicago lupulina, Onobrychis sativa, Ornithopus sativa, white sweet clover, Melilotus alba, and blue sweet clover, Melilotus caerulea. The other account deals with the distribution of stem rot and with the life history and nomenclature of the

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fungus which is designated, Sclerotinia trifoliorum Erik. In 1890 (19) the disease was reported as more destructive to Medicago lupulina in Denmark than to species of Trifolium. Subsequent accounts by European investigators deal primarily with experimental procedures looking toward the control of the disease.

Stem rot has not only been prevalent in continental Europe, for a long time, but it very probably was the cause of lands becoming "sick of red clover," hence the name clover-sickness in the British Isles, as early as the early part of the nineteenth century. Investigations on clover sickness were begun at the Rothamsted Experiment Station, England, in 1849 (12) but the relation of the disease to the fungus Sclerotinia trifoliorum was not established until 1897 (3). English writers had previously expressed a variety of views in regard to the cause of clover sickness. Carruthers (3) at this time ascribed the disease to the fungus in question and suggested methods for its control.

The first observation of the occurrence of clover stem rot within the United States appears to have been made in 1890 in Delaware (2). While the disease was during subsequent years noted in several other States, it appears not to have been sufficiently destructive to incite investigation. In 1914-1915, however, it was reported by Gilbert and Myer (10) to be productive of serious damage to young alfalfa plants in Kentucky. This report and a subsequent one (11) constitute the only American accounts which indicate any considerable study of the disease.

Distribution of the Disease

As indicated above, the disease is known to occur abroad in Germany, Denmark, Sweden, and England, and in America within Delaware and Kentucky. It has furthermore been recorded from Canada, New York, New Jersey, Virginia, Indiana, Oregon, and North and South Carolina. Its prevalence in these states indicates that it very probably occurs in other of the states where clover is grown. Its distribution within North Carolina is not completely known, but since clover is generally grown throughout the State and since the points from which collections of diseased material have been made are quite widely separated, it is believed that the disease is generally prevalent. As indicated by these collections the disease is known to occur within thirteen counties, namely: Alamance, Chatham, Columbus, Edgecombe, Forsyth, Granville, Halifax, Lincoln, Mecklenburg, Moore, Orange, Rowan, and Wake.

Host Plants

The disease has been shown by European writers to attack red clover, white clover, crimson clover, alsike clover, sainfoin and alfalfa. To this list Gilbert and Myer (10) have added spotted spurge, Euphorbia macu-

lata. Frank (7) observed a sclerotial disease of peanuts of whose identity he could not be certain since he did not have the apothecial stage, but he may have been dealing with the same organism.

Names of the Disease

As is the case with many plant diseases, various common names have been applied to this disease, although the name stem rot seems to be most appropriate. Among other names which have been employed are clover rot, wilt, and root rot. In England the name clover sickness has long been employed and other European accounts make use of the names Sclerotium rot, clover rot (Kleefaule), and clover canker (Kleekrebs).

Description of Clover Stem Rot

Stem rot on crimson clover can first be noticed in the fall when the plants are still small. It continues to spread, however, when weather conditions permit, throughout the winter months and is destructive until the time when unaffected plants are mature. The first evidence of the presence of the disease is manifested by a wilting of the stem and leaves. These portions then turn yellowish, rather quickly succumb and become brown (Plate 3, Fig. 1). Closer examination discloses the fact that the stems near the base of the stool or at the ground level are involved in decay, which begins as a slight discoloration and proceeds until the stems have rotted off. At this time a dense, white, mold-like growth is prominently present at the base of affected stems. In the presence of a suitable supply of moisture this fungous growth becomes more profuse and within a few days, compact masses of hyphae will have formed on the surface of the decaying stems (Plate 3, Fig. 1). These masses soon become black in color and of a cartilaginous consistency and are the sclerotial stage of the causal organism.

These black sclerotia are sometimes as large as a pea and their presence can be used as an aid in a field diagnosis of the disease. With the maturing of these sclerotia and the simultaneous disintegration of the stems, the sclerotia remain scattered over the soil where the plant has been. Meanwhile, the roots also are involved in decay and the sclerotia which are formed as the tissues become decomposed, remain in the soil. Since the disease spreads outward from a center of infection, plants in all stages of the disease may be found in any one spot. When the diseased areas are large the centers may be entirely bare or there may remain the debris of the badly decayed stems. The stand of clover, in case plants die in localized areas, is thus rendered not uniform or when the centers of infection are numerous and extremely favorable conditions prevail, the stand may be rather uniformly destroyed.

Etiology

Clover stem rot is caused by a discomycetous fungus, Sclerotinia trifoliorum Erik. This organism is identical with the one which was first illustrated by Hoffmann (13) in 1863, but to which he applied the name Peziza ciborioides Fries. Furthermore, it is the same as the one which is so fully described by Rehm (18) and which he designated as Peziza ciborioides Fries. The organism which was originally identified as Peziza ciborioides by Fries (9) in his Systema Mycologicum, as has been pointed out by Eriksson (6), is entirely different from the clover stem rot fungus. In the first place, Fries makes no mention in his description of Peziza ciborioides of sclerotia, structures which could not have escaped his notice had he been working with the fungus on clover. Then, too, he states that the fungus grows early in spring upon stems in moist places and heathes, whereas the clover rot fungus appears in Sweden during the fall upon the collar of clover plants. Both the time of appearance and the habitat of the fungi, therefore, fail to accord. It was for these reasons that Eriksson regarded Peziza ciborioides Fries as applying to a form entirely distinct from the clover stem rot organism.

Güssow (12) has suggested that the combination Sclerotinia ciborioides Rehm is the most tenable name. In the light of the fact, however, that Rehm (18) misidentified Fries' species there appears to be little reason for retaining the specific name ciborioides, when the proper generic name Sclerotinia instead of Peziza is employed.

Morphology of Sclerotinia Trifoliorum

Although several careful investigations on the morphology of the stem rot fungus have been reported, this phase of the problem is given attention at this time because of certain statements in recent bulletins and text-books bearing on the relationship of Sclerotinia trifoliorum and Sclerotinia libertiana. In a bulletin dealing with wilt of alfalfa in New York, for example, Stewart, French and Wilson (22) state "that the fungus causing the disease is supposed to be the Sclerotinia trifoliorum Erik, given in all text-books on plant diseases as the cause of a stem rot of clover and which is said to attack also alfalfa. However, Prof. R. E. Smith, to whom specimens were sent, reported (20) that "the sclerotia were entirely similar to those of Sclerotinia libertiana and that they produce a Peziza form which leaves no doubt that the fungus really is Sclerotinia libertiana." Duggar (5) states that some regard the clover stem rot fungus as identical with Sclerotinia libertiana. Stevens (23) states that they are "by some regarded as identical; sufficient evidence has, however, not been adduced to prove them the same." More recently Smith (21), in an investigation of cottony rot of lemons in California, caused by Sclerotinia libertiana, has noted that the same

organism attacks alfalfa and vetch. It seems desirable, therefore, that a comparative study of Sclerotinia trifoliorum and S. libertiana be made to establish their relationship to each other. They were accordingly isolated from crimson clover and from lettuce respectively and maintained in culture under observation for a considerable period.

The mycelium or vegetative body of the clover stem rot fungus appears under no conditions, except in the formation of sclerotia, to produce an abundant aerial growth on the surface of stems. It is then not loose and cottony, as in the case of lettuce drop fungus, in which there is a profuse mycelium, especially under conditions of high relative humidity. This is in accord with observations by Gilbert and Meyer (10) on Sclerotinia trifoliorum and Stevens and Hall (24) on Sclerotinia libertiana. Furthermore, constant differences in mycelial development are apparent in culture. On steamed cornmeal or potato agar, media noted to favor rapid growth of both organisms, S. libertiana makes the more luxuriant, rapid growth, a difference which persists even after sclerotial formation has been completed. Even though there is considerable variation in diameter of the hyphae, with an overlapping of extremes, the lettuce drop fungus possesses the larger, coarser mycelial threads. Comparative measurements of the younger growing tips, as shown in Plate 1, Fig. 1, indicate that the relative diameters are approximately in the proportion of 2 to 3.

It does not appear to be possible to differentiate between the peculiar processes termed attachments, which have been described in previous accounts and which develop when contact between hyphal tips and wall of the culture flasks or Petri dishes is effected. In the case of each organism, the hyphae become flattened, septate, profusely branched and interlaced resulting in the formation of dark masses which adhere to the glass surfaces.

The sclerotia of both are variable in shape, in that they are spherical, cylindrical, flattened or irregular, and in size which ranges in the case of S. trifoliorum from .3 to 10 mm. and to as large as 20 mm. in S. libertiana. In general, the latter is considerably larger as indicated in Plate 2, Fig. 2. No differences in development or structure were noted, however. From 2 to 3 weeks are required for their formation. They begin as dense, floccose, white mycelial masses. After a few days the masses have increased in size, become compact and of a cartilaginous consistency. At this stage they are white to pale cream-colored, which color persists within although the exterior rapidly changes to an inky black. In culture on flasks of steamed corn meal, very abundant sclerotial formation results, forming in some instances, a sclerotial crust over the entire surface in the case of the clover stem rot organism, whereas the sclerotia remain for the most part separated in S. libertiana.

No observable differences were noted in the size and manner of production of the apparently functionless microconidia. These structures are small, spherical bodies, 2 to 4 mikra in diameter, which are abstricted in acropetal succession from flask-shaped cells. These cells may appear as lateral or terminal branches from the vegetative hyphae, Plate 1, Fig. 2, or from the germ tubes produced in the germination of the ascospores. Microconidia may form in conspicuous, grayish, mealy patches on the surface of the mycelium in culture. They have not been observed to germinate except by the formation of a hypha 2 or 3 mikra long, nor has it been possible to bring about infections with them. This accords with the results by others, among whom are Coleman (4). During April, 1916, twenty crimson clover plants were sprayed with a suspension of microconidia from S. trifoliorum, were then covered to conserve moisture but no sign of infection was subsequently noted.

The macroscopic characters of the apothecia cannot be employed in differentiating the two forms. The stipe and disc are yellowish brown in color. The stipes are variable in length, depending upon the depth below the surface of the soil to which the sclerotia are buried. In extreme cases their length varies from 3 to 30 mm. and their thickness from 1 to 2 mm. The discs are at first deep cup-shaped, but expand to a flat disc, 3 to 10 m.m. in diameter, the margin of which may become reflexed and fissured, Plate 1, Fig. 4. Apothecia of both species have been secured by the writers by burying selerotia from 2 to 9 months in moist sand in flower pots. Sclerotia of S. trifoliorum which had been matured in culture in July, 1910, were planted during September and they had developed fruiting discs by December, Plate 3, Fig. 2. Comparative measurements of asci and ascospores from these apothecia, as indicated in text, Plate 1, Fig. 3, show that the asci and ascospores of S. trifoliorum are very manifestly larger than those of S. libertiana which facts accord with observations of other investigators. These data are assembled in the following tabulation:

Sclerotinia Trifoliorum			Sclerotinia Libertiana		
Author	Size of Asci	Size of Ascospores	Author	Size of Asci	Size of Ascospores
Rehm	160x10*	15-17x8-10*	Saccardo ..	130-135x 8-10*	9-13x4-6.6*
Eriksson	180x12*	14-18x8*			
Kuhn	160-180x14*	16-20x8-10*	Stevens & Hall	82-2(?)	8.7-11.6x5.8*
Present writers...	140-160 8-11*	12-14x8*	Present writers...	95-120x 8-9*	7-9x6*

*Mikra.

Life History of the Causal Organism

The life cycle of the clover stem rot fungus is relatively simple since it possesses only one functional type of spore. It lives for the greater part of the year as a saprophyte and can maintain itself in the soil upon decaying plant tissues from one year until the next. On the basis of difference in appearance and function, the fungus may be regarded as possessing three stages. Under normal conditions the first or vegetative stage is present during late fall, winter, and early spring, within the clover plants causing their death. Invasion of the tissues begins at the collar, near the ground level, and extends upward and downward from this point of attack. During the same period the fungus continues its vegetative growth as a saprophyte in plants which it has killed. As the tissues are disintegrated the fungus appears at the surface of the decaying parts and becomes massed together in compact black sclerotia, the second stage. These sclerotia then remain dormant on the surface of the soil or within the soil in the spots left bare by the destruction of the clover. Since these sclerotia require only two or three weeks to mature they are being formed practically throughout the entire growing period of the clover crop. These sclerotia, which contain a reserve of nutriment, remain dormant and serve to carry the fungus over the summer season, or until opportune conditions for their growth again prevail. During the fall and early winter these sclerotia germinate by the formation of slender, yellowish-brown stalks. The distal ends of these stalks expand into the disc-shaped fruit bodies, which with the stalks constitute the apothecia, the third stage. From one to a half dozen apothecia are developed from each sclerotium, depending upon the size of the sclerotium. The upper or inner surface of these discs is lined with a layer of closely aggregated, elongated sacs, or asci, interspersed with the paraphyses. Rehm (18) has estimated that there are approximately 5,000 sacs in one square millimeter of surface, each of which bears at maturity eight ascospores. These ascospores are forcibly discharged, often in such numbers as to appear like small clouds of dust. They may then be carried by the wind to a moist surface and there germinate at once by the formation of a hypha. This hypha becomes, as growth proceeds, the vegetative mycelium, thus completing the cycle of development.

Whether these ascospores directly infect clover is not known, aside from the experimental work of Rehm (18) and Coleman (4). The former suspended mature fruit bodies over healthy plants and within 6 to 8 days the mycelium was present within the leaf blades, the plants subsequently collapsed, and sclerotia were formed in due time. He did not determine the mode of entrance of the germ tubes, but regarded it as probable that they entered through the stomates. The latter reported that young clover plants only can be readily infected by ascospores,

although under favorable conditions older plants were in a few instances attacked. His investigations furthermore led him to assert that infection does not take place through the stomates, but by penetration of the epidermal cell walls. The results of direct infection of lettuce by ascospores of Sclerotinia libertiana led Stevens and Hall (24) to conclude that it seldom, if ever, occurs, and that the fungus becomes parasitic only after it has maintained itself for a time, as a vigorous saprophyte. Because of the fact that infection begin on the stems at or near the ground level in the case of stem rot of clover, it is believed that the vegetative mycelium is responsible for the disease and that little disease results naturally by direct infection with ascospores.

Infection Experiments

Several series of artificial inoculation tests have been made during the past two years. These involved plants of crimson clover, red clover, and lettuce grown within the greenhouse in flats or in beds, and crimson clover, hairy vetch, Vicia villosa, and lettuce grown under field conditions. Inoculation in the greenhouse was accomplished by introducing the appropriate organism from cultures on steamed rice or steamed corn meal or from diseased plant parts into the soil near the collar of the plants. Wilting was apparent within 8 to 10 days in the case of lettuce, crimson clover, or red clover, when either Sclerotinia trifoliorum or S. libertiana were employed. Practically all of the inoculated plants succumbed, irrespective of whether the inoculum consisted of pure cultures or of decaying plant tissues.

During April, 1917, plants of crimson clover and vetch five to eight inches in height were inoculated in the field by parting the stems and placing at the center of the plant fragments of lettuce affected with drop, S. libertiana. The plants thus inoculated were then lightly covered for 36 hours with a newspaper weighted at the corners. Five days after inoculation many of the younger stems near the center of the rosette were dead and their tissues involved in decay. The copious superficial mycelial growth was like that of the lettuce drop organism. Within twelve days even the larger stems had begun to wilt. Stem rot had never been present in this field and only the inoculated plants were affected. Furthermore, lettuce plants in another field were inoculated on the same day by inserting diseased lettuce leaves into the heads. These plants were in an advanced stage of drop a week later.

During November, 1917, crimson clover in the field was inoculated by placing in the soil pure cultures on corn meal of S. trifoliorum and of S. libertiana. Four weeks later circular areas eight to ten inches in diameter in which all of the plants were dead, had formed around the

place of inoculations with each of the organisms. Lettuce plants, furthermore, became affected when diseased clover plants were transplanted beside them. These reciprocal inoculations leave no doubt that both clover and lettuce may be attacked by either S. trifoliorum or S. libertiana. Smith's (21) observations on the cause of cottony rot of lemons are of interest in this connection since he states that their decay is due to S. libertiana, although S. trifoliorum is able to develop on artificially inoculated lemons and may cause some of the infection. He also points out that alfalfa and vetch when grown as cover crops in lemon groves are attacked by S. libertiana. The confusion which has existed in the literature dealing with the identity and relationship of S. trifoliorum and S. libertiana is, therefore, clarified by these reciprocal inoculations which are in part a confirmation of studies and observations by Smith (21).

Means of Spread of Stem Rot

It seems highly probable that stem rot of clover was introduced into America from Europe, but the method of its introduction, together with the means for its spread into new localities each year, have remained more or less problematical. Eriksson (6) states that the fungus undoubtedly overwinters as hyphae adhering to the seeds and not as sclerotia or spores and that the disease is spread by this means.

Coleman (4) suggests that sclerotia mixed with the seed are a probable means of the distribution, although spores adhering to the seeds are also a possible means. Observations on this point, first made during the fall of 1914, by Prof. H. R. Fulton, then Plant Pathologist for the North Carolina Experiment Station, show that sclerotia are present in commercial crimson clover seed. He states:* "I received from county agents some six or eight samples of seed. Two of these, I distinctly remember, showed the contamination with sclerotia." If seed were harvested from affected fields, sclerotia would almost certainly be mixed with seed (Plate 2, Fig. 3), and would remain with them even though the seed were very carefully cleaned. Seed contaminated with sclerotia are, therefore, believed to account for the introduction and presence of stem rot of clover.

Numerous possibilities might be suggested to account for the local distribution of the disease. The fungus is known to spread through the soil along the margin of the diseased areas. Further, the sclerotia which normally remain dormant for a time, even though favorable conditions for their germination may obtain and which may retain vitality for at least two and one-half years under laboratory conditions and one and one-half years in the soil (18) may aid in its spread. They may be dis-

*From a letter dated October 25, 1917.

tributed by the implements used in cultivation, by the use of soil in inoculating with the nodule forming organism, by rains, or by being harvested with the hay crop. If this hay is fed to stock the possibility exists of the return of these sclerotia to the fields through the manure.

The violent discharge of ascospores from the mature apothecia and the carriage of these spores by the air currents may also be taken into account in the local spread for short distances of the stem rot fungus.

Methods of Control

A very considerable body of data and observations bearing on methods of control have been presented in published accounts of stem rot. Much of the experimental work is of value, however, only inasmuch as it indicates methods which cannot be employed with success. In the light of the facts which have been presented relative to the life history of the causal fungus, some of these experimental results are to be anticipated. This may be instanced by the work with fertilizers and manures at the Rothamsted Experiment Station (16) which was based on the assumption that "clover sickness" is due to unfavorable soil conditions. No appreciable differences in treated and untreated plots were noted, results in agreement with those of Rehm (18) and others who have performed less extensive tests. Among the different fertilizers which have been applied are guano, barnyard manure, compost, bone meal, woodashes, gypsum, and lime. In the Essex experiments (1), where ground limestone was employed, clover remained free from disease. Causes other than the use of lime are believed to have been operative in this case, since these results do not accord with those just presented nor with the more recent ones of Coleman (4).

Among the cultural practices which have been noted to be of benefit by Freckmann (8) and Gilbert and Myer (10) are deep plowing. This was suggested from experiments by Rehm (18) in which sclerotia were buried at different depths in garden loam. No apothecia were developed when sclerotia were covered as deep as eight cm., about 3 inches. Rehm further pointed out that buried sclerotia were subject to destruction by earthworms, wireworms, millipeds, and mites. During the season of 1917 the sclerotia which were covered with sand in the studies on apothecial development were, in several series, noted to be completely devoured by fungus gnats, Mycetophilidae. The burial of sclerotia particularly when the soil is kept moist favors their decay from natural causes. Complete decay of the sclerotia of Sclerotinia trifoliorum was observed by the writers to be accomplished within two months. Stevens and Hall (24) have reported that under natural conditions the number of sclerotia of S. libertiana is greatly reduced by decay.

Precaution should be exercised both in the saving of seed from affected crimson clover fields and the planting of such seed because of its contamination with sclerotia. To guard against the introduction of stem rot into new fields or new localites, seed should be sampled and sent to a seed testing laboratory in advance of purchase. The introduction of the disease through manure from stock fed on hay from affected fields is also to be guarded against.

It is known that not all host species are equally subject to attack by S. trifoliorum, but whether or not any one of these species possesses marked varietal differences in susceptibility is not known. No experimental work appears to have been done on selection for disease resistance and the only observation that has come to our attention that such differences exist is by Nilsson-Ehle (17) who records that Swedish red clover of the variety serotinum is more resistant than exogenous strains.

In fields badly infested no measures can be relied upon to be effective other than the adoption of a proper rotation system in which clovers are not grown for a period of three or four years. Definite data are wanting on the length of time which the stem rot organism can live saprophytically in the soil, but it is logical to assume that it would no longer be present or the infective material would at least be greatly reduced in amount within a lapse of three or four years. Cowpeas and soybeans which are not subject to attack by Sclerotinia trifoliorum may well be used as a leguminous crop in such a system of rotation and winter oats and rye can be employed as winter cover crops.

Summary

1. Stem rot of clover is a fungous disease quite widely prevalent upon crimson clover within North Carolina.

2. Other kinds of legumes as red clover, white clover, alsike clover and alfalfa are subject to the same disease.

3. Stem rot occurs in several states and has been known in America since 1890. It was present in England over one hundred years ago, where it caused failures of red clover and was popularly called clover sickness. The disease was first reported in continental Europe in 1857.

4. The disease is prevalent from October to March and may be recognized by (1) a sudden wilting and death of plants in spots; (2) a rotting off or decay of the stems near the surface of the ground; (3) the presence of black sclerotia on the decaying stems.

5. The causal organism was first described in 1863 as Peziza ciborioides Fries. Since this was a mistaken identification it was in 1880 given the name Sclerotinia trifoliorum Erik, which name has been employed in the present account.

6. The fungus may be said to possess in its life cycle three stages, a vegetative or mycelial stage, a sclerotial stage, and an apothecial or ascogenous stage.

7. A study has been made of the development of S. trifoliorum from diseased crimson clover in comparison with S. libertiana from lettuce affected with drop. The two differ in luxuriance of mycelial growth, size of hyphae, size of sclerotia, and size of asci and ascospores.

8. In the infection experiments S. trifoliorum has been successfully inoculated into lettuce and crimson clover and S. libertiana into lettuce, crimson clover, and vetch.

9. The comparative morphological studies indicate that S. trifoliorum and S. libertiana are distinct species. Furthermore, the reciprocal inoculations clarify existing accounts of the identity and relationship of the two organisms.

10. The feature of most economic importance in the life history of the stem rot fungus is that the sclerotia may be mixed with the seed at time of harvest. The planting of such contaminated seed then insures the spread of the disease to new localities. Other agencies as implements, soil, and hay from infected fields may serve as a means of spread.

11. The sclerotia which remain dormant in infested soils constitute the means of keeping the organism alive where the disease has once appeared. Burial by deep plowing prevents their germination and thus prevents the spread of stem rot. Many sclerotia decay from natural causes and many are destroyed by insects.

12. Introduction of the disease into fields where it is not yet present should be prevented by avoidance of contaminated seed, by the exercise of care when soil is used to inoculate new fields with the legume nodule forming bacteria, and by not returning manure to clover fields when hay from infested fields has been fed.

13. The adoption of a system of crop rotation is the only reliable means of control for infested fields. Cowpeas and soybeans can be used in this rotation system to increase and maintain soil fertility, and winter oats and rye can serve as cover crops.

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EXPLANATION OF ILLUSTRATIONS

PLATE 1, FIG. 1—(a) Hypha of Sclerotinia libertiana and (b) of S. trifoliorum from the margin of colonies on potato agar showing relative size of the two species.

PLATE 1, FIG. 2—Microconidia (a) of Sclerotinia libertiana and (b) of S. trifoliorum borne on hyphal branches in old cultures.

PLATE 1, FIG. 3—Asci and ascospores (a) of Sclerotinia trifoliorum and (b) of S. libertiana, drawn with the same magnification.

PLATE 1, FIG. 4—Apothecia of S. trifoliorum developed from sclerotia.

PLATE 2, FIG. 1—Normal plant of crimson clover of the same age as the diseased ones shown in Plate 3.

PLATE 2, FIG. 2—Sclerotia (a) of Sclerotinia trifoliorum and (b) of S. libertiana, natural size.

PLATE 2, FIG. 3—Crimson clover seed contaminated with small sclerotia, which can scarcely be distinguished from the seed.

PLATE 3, FIG. 1—Plants of crimson clover affected with stem rot, S. triofoliorum, showing several stages of the disease. Sclerotia have formed on the stems as indicated by the direction of the arrows.

PLATE 3, FIG. 2—Apothecia of S. trifoliorum developed from sclerotia grown in pure culture and buried in sand.

PLATE 1

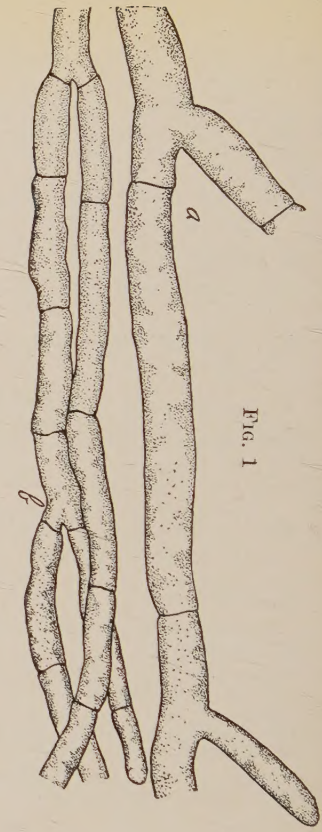


FIG. 1

FIG. 2

FIG. 4

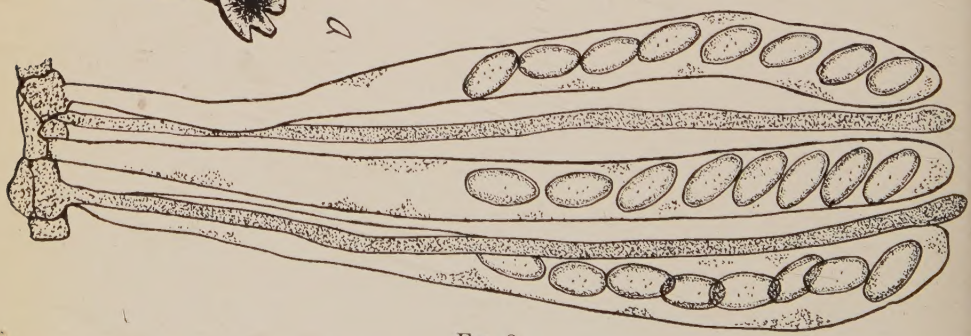
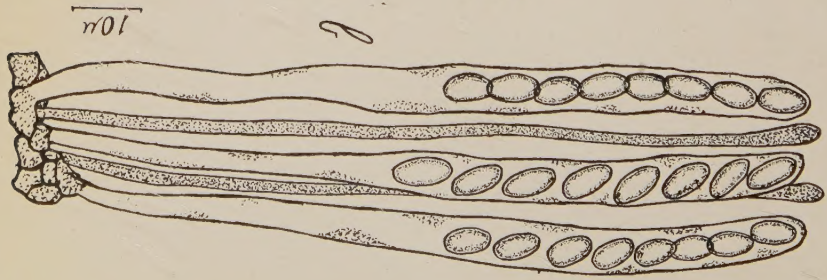


FIG. 3



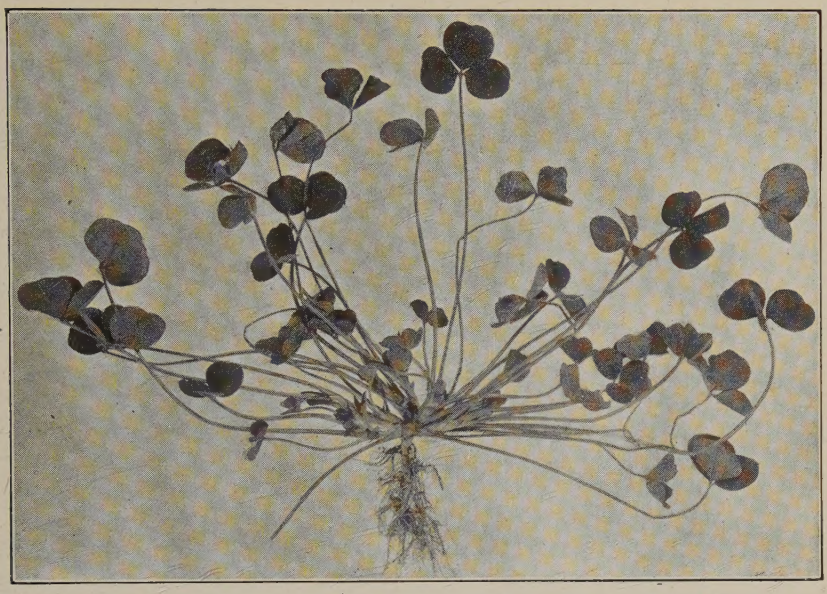


FIG. 1

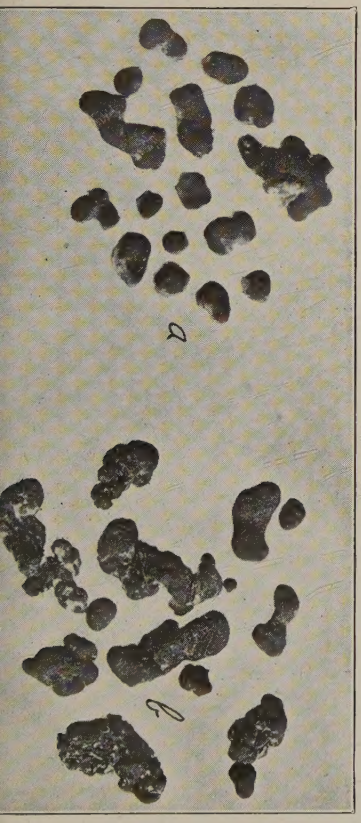


FIG. 2

FIG. 3

PLATE 3

FIG. 1

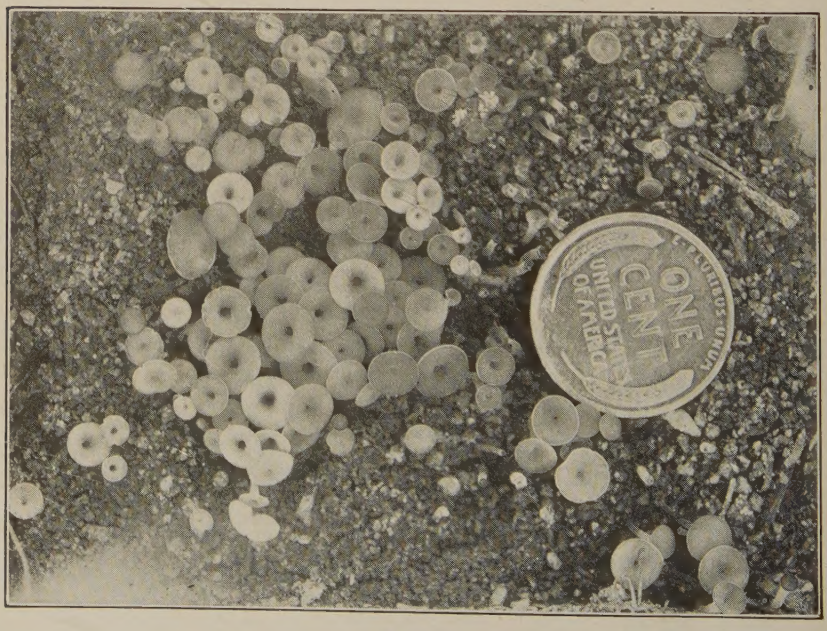


FIG. 2